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BLOOD LACTATE RESPONSE TO THE CF EXPRES TEST

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ABSTRACT

This study evaluated the blood lactate (LA) response to stepping exercise, specifically the Canadian Aerobic Fitness Test (CAFT). It also compared the ability of lactate and heart rate at a given stage of the step test to predict maximal aerobic power ($\dot{V}O_2$max). Sixty-nine male and female CF personnel between the ages of 30 and 50 years participated in this study. The LA concentration after each stage of the CAFT was measured in all subjects by sampling blood from the finger-tip. Eighteen of these male subjects also had their $\dot{V}O_2$max measured directly during a maximal treadmill run. The analysis of the data showed that the step test significantly raised LA in both the male and female subjects ($p<.05$). When the LA and heart rate measures at stage four of the step test were compared for their ability to predict treadmill $\dot{V}O_2$max, LA was the better predictor. The correlation between lactate and $\dot{V}O_2$max was -0.33, while between heart rate and $\dot{V}O$2max it was -0.02. These preliminary results suggest that lactate measured during the CAFT is at least as good and perhaps a better predictor of $\dot{V}O_2$max than heart rate.

INTRODUCTION

The Canadian Forces (CF) adopted the CF EXPRES test as the annual physical fitness testing procedure in 1983. This test is identical to the Canadian Standard Test of Fitness (2,11,17). The CF EXPRES test includes assessments of maximal aerobic power (MAP), muscular strength, muscular endurance and body composition. MAP is evaluated by the heart rate response to a step test protocol. Hand grip strength is used as an index of total body strength. Muscular endurance is evaluated from sit-up and push-up performance. Body composition is assessed from skinfolds, circumferences, height and weight measures.

Recently the CF has proposed minimum standards in physical fitness for all CF personnel. The intention is that all CF personnel will be required to meet these standards or be subject to remedial physical training programmes and potentially, adverse career action. The accuracy of the EXPRES test battery thus assumes considerable importance. In contrast to the direct quantification of strength and muscular endurance, MAP is predicted from the heart rate measured during the stepping activity. The test does not measure aerobic power directly. It is, therefore, subject to error, exemplified by the moderate correlations reported between direct tests of MAP and the step test predicted values, r=.67 - .82, (3,4). At best 67% of the variance in directly measured MAP among individuals can be explained by the predicted MAP; in some subject samples only 45% of the variance is explained. For example, Bell and Allen (3) reported that for a directly measured MAP value of 40 $ml \cdot kg^{-1} \cdot min^{-1}$ in a 30 yr old male the step test predicted value could range from 33 to 53 $ml \cdot kg^{-1} \cdot min^{-1}$, corresponding to the 5th and the 95th percentile of Canadian norms (11). Such potential errors in evaluation are obviously not acceptable when career action may be involved. Therefore, a more precise method of evaluating the ability to perform aerobic exercise other than heart rate would be advantageous.

The blood lactate response to submaximal exercise has been repeatedly shown to be an accurate means of assessing aerobic physical fitness (14,15). "Lactate-related variables account for a larger proportion of the variation in endurance performance than other variables tradition-

ally determined in the exercise laboratory - including the measurement of maximal aerobic power ($\dot{V}O_2$max)" (14). This statement refers to directly measured $\dot{V}O_2$max, and should be all the more emphatic if a lactate evaluation is compared to a predicted $\dot{V}O_2$max, as in the CF EXPRES test. Moreover, the blood lactate response is not affected to the same extent as is heart rate by factors such as anxiety, environmental temperature and pharmacological agents. The latter factor is particularly noteworthy considering the significant number of older CF personnel treated for hypertension with β-adrenergic blocking agents. Such drug treatment invalidates the use of the present EXPRES step test to evaluate endurance fitness because of the marked effect on heart rate. In addition, blood lactate is more sensitive to improvements in endurance fitness than is $\dot{V}O_2$max (14).

Therefore, this study was undertaken to determine the blood lactate response to the CF EXPRES step test, and to compare the predictions of MAP using the standard heart rate protocol to those using the blood lactate response to the same step test.

METHODS

Subjects

Sixty-nine CF personnel (44 men and 25 women), aged 30-54 yrs, participated in the study. These personnel were selected from various Canadian Force bases (i.e. Kingston, Ottawa or Trenton). They represented a wide spectrum of age, and physical fitness levels, ranging from the very fit to the very unfit. The physical characteristics of all the subjects, including their predicted and directly measured $\dot{V}O_2$ max, are presented in Table 1.

Test Procedures

Before commencing the various tests, each subject completed the Physicl Activity Readiness Qauestionnaire, PAR-Q, (7) and signed an informed consent form. Each subject performed the step test as described in the CF EXPRES (6) with heart rate measured via a bipolar ECG recording instead of manual palpation of the pulse. All subjects age 30-50 yrs started at the stage two stepping frequency appropriate for their gender. Those individuals over 50 yrs

had the option of starting at stage one or two. Immediately upon completion of each stage heart rate was measured for ten seconds, as per the testing protocol, and a 20 µl capillary blood sample was taken from a finger prick. The subjects were allowed to progress to the next stage as long as their heart rate was at or below the heart rate guidelines described in the CF EXPRES (6). Based on the heart rate measured during the maximum allowable exercise stage, their $\dot{V}O_2$ max was predicted using the CF EXPRES aerobic calculator.

The blood taken after each stage of exercise was immediately expelled into 200 µl of cold 0.4 M perchloric acid and stored on ice. All samples were stored at -80°C until assayed for their lactate concentration (21).

Twenty-two of the subjects (18 males and 4 females) volunteered to perform a $\dot{V}O_2$ max test on the treadmill. Heart rate was monitored with a three lead ECG system to obtain their maximum heart rate. Oxygen consumption, carbon dioxide production and ventilation were monitored with an automated metabolic cart (Alpha Technologies®). After a 2 min familiarization walk at 4.8 km/hr, a continuous protocol of progressively increasing speed and grade was utilized to reach the subject's $\dot{V}O_2$ max. $\dot{V}O_2$ max was defined by a plateau in oxygen consumption with an increasing minute ventilation or by subject volitional fatigue. The highest value in oxygen consumption measured during the test was considered as the $\dot{V}O_2$ max.

Treatment of Data

Standard statistical measures were used to determine the means and standard deviations. Pearson product correlations were used to determine "r" values. A one-tailed test was used to evaluate the significance of the correlation. Stepwise regression analysis was used to derive a regression equation to determine the best predictors of MAP. All statistical processing was performed using BMDP software (10) on a SUN workstation.

RESULTS & DISCUSSION

The purpose of this study was to examine the feasibility of using the blood lactate response to the EXPRES step test to evaluate aerobic fitness. Table 2 describes the blood

lactate response to the stepping exercise (means ±SD and range of values) at each stage of the EXPRES test for both the male and female subjects. It is apparent from the blood lactate response that the stepping exercise, although submaximal in intensity, is sufficient to markedly raise blood lactate levels. The range of blood lactate concentrations measured indicates that the EXPRES raises lactate values sufficiently so that they can be within the 3-5 mM range. This range has been earlier demonstrated to be appropriate to predict endurance performance (13,14,15). It, therefore, appears feasible that blood lactate measures could be used in conjunction with the CF EXPRES step test without altering the test protocol to evaluate aerobic fitness of CF personnel.

Why use blood lactate to evaluate aerobic fitness? Firstly, it has been shown that lactate-related variables account for a larger proportion of the variation in endurance exercise performance than any other variable traditionally measured in the exercise laboratory, including the measurement of $\dot{V}O_2$max (14). Secondly, blood lactate can be easily sampled and measured. Thirdly, there is a small but significant proportion of the CF personnel who are presently not tested because they are being treated with β-blockers. These drugs are used to control hypertension. Beta blockers cause a moderate decrease in blood pressure, a pronounced reduction in heart rate, and no change in stroke volume (1,8,19,23). As a consequence, the prediction of $\dot{V}O_2$max from heart rate of personnel treated with β-blockers therapy is invalid. β-blockers do not markedly affect the lactate response to exercise during submaximal exercise (18). β-blockers may, however, reduce the lactate accumulation after maximal exercise. The reduced lactate response appears to be secondary to the reduced O_2 uptake at maximal exercise (18).

This study was also undertaken to compare the strength of the prediction of MAP determined by heart rate with that determined by blood lactate. Table 3 describes the Pearson product correlations between the four best predictors of $\dot{V}O_2$max. Only the data for the 18 male subjects who completed both stage 4 of the EXPRES test and the maximal treadmill test were used to evaluate these correlations. An "r" value of 0.4 was needed for statistical significance

($p < 0.05$). Although none of the variables reached this level, the best predictor for $\dot{V}O_2$max was blood lactate followed by age, weight and the fourth stage final heart rate. Higher correlations were anticipated; however, the unfamiliar treadmill protocol, the unwillingness of subjects to push themselves to a true maximal level and the small sample size probably accounted for the reduced r values. Nevertheless, the results suggest that lactate measures rather than heart rate measures would be better predictors of MAP.

Table 4 shows the multiple correlations derived from a stepwise regression to predict treadmill $\dot{V}O_2$max without the heart rate measure. Again only the data for the 18 male subjects who completed both the CF EXPRES test and the maximal treadmill test were used. The independent variables used in the regression included lactate plus the three other variables normally used in the CF EXPRES, i.e., final stage estimated $\dot{V}O_2$, age, and weight. It should be noted that the lactate values used were those measured at stage 4 of the step test. The variables are entered or removed according to their ability to predict treadmill $\dot{V}O_2$max. The multiple R is reported as each variable is added into the prediction. The greatest proportion of the predictability comes from blood lactate and age with only slight improvements in the prediction by the addition of the remaining variables, final stage $\dot{V}O_2$ and weight. The present data again support the conclusions of Jacobs (14), Jacobs et al. (16), and Kumagai et al. (20) which suggest that lactate is the best predictor of aerobic performance. The equation to predict $\dot{V}O_2$max from the multiple linear regression analysis is shown below.

$$\dot{V}O_2\text{max} = 73.5 - 0.59 \cdot age + 0.04 \cdot wt - 2.98 \cdot lactate - 2.53 \cdot finalstage\ \dot{V}O_2$$

The monitoring of individuals on training programs is important to show progress, especially in the CF when an individual is put on remedial physical training. However, Bell and Jacobs (5) reported that the EXPRES step test was insensitive to directly measured training induced changes in MAP in flight crew who had been engaged in 12 weeks of circuit training. In contrast, the results of several other studies (9,14,22) suggest that lactate is a more sensitive indicator of training adaptation than is $\dot{V}O_2$max. These studies showed a greater change in the

lactate variable compared to the $\dot{V}O_2$max variable.

It is interesting to note that at least one NATO country, Norway, has recently decided to adopt a lactate based exercise test for their recruitment test battery (12). For their compulsory test of aerobic fitness, all Norwegian conscripts will perform a 6-7 min submaximal treadmill walking test. At the end of the walk a blood sample is obtained from the fingertip and immediately analysed with an automatic lactate analyser (12). The conscripts fitness level is assigned based on the lactate concentration, i.e., the lower the concentration the fitter is the conscript. The Norwegians are planning to administer this test not only at recruitment centres in the larger urban centres but also in their mobile testing units which are responsible for the conscripts living in rural areas. The replacement of the present heart rate based test with a test involving blood sampling is thus a very feasible alternative.

There is enough evidence in the present report and other scientific literature to support the use of blood lactate concentrations instead of heart rate for evaluating aerobic fitness and for monitoring training progress, especially in those CF personnel using β-blockers. There are, however, many technical problems to be resolved before routine lactate analysis can be performed in conjunction with the CF EXPRES test and training programs. The initial task should be to evaluate, more completely, the lactate response to the CF EXPRES test and relate this to the aerobic performance of CF personnel.

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Table 1: Physical characteristics of the subjects who participated in the CF EXPRES step test and the maximal treadmill test.

	EXPRES Step Test		Treadmill Test	
	Males (n=44)	Females (n=25)	Males (n=18)	Females (n=4)
Age *yrs*	42.2 ±5.3	36.6 ±3.6	40.7 ±5.0	37.7 ±3.9
Weight *kg*	81.0 ±18.0	65.0 ±9.6	79.4 ±14.2	64.4 ±3.4
Height *cm*	172.8 ±6.6	163.9 ±6.0	172.3 ±7.3	169.0 ±6.3
Predicted $\dot{V}O_2$ max* $mL \cdot kg^{-1} \cdot min^{-1}$	38.7 ±5.9	32.9 ±3.6	39.3 ±5.5	33.9 ±3.8
Measured $\dot{V}O_2$ max** $mL \cdot kg^{-1} \cdot min^{-1}$	-	-	38.4 ±8.4	39.5 ±8.6

means ±SD

* CF EXPRES step test

** Treadmill test

Table 2: Blood lactate (mM) at each stage of the EXPRES step test.

Stage	Males			Females		
	No. of Samples	Mean±SD	Range	No. of Samples	Mean±SD	Range
1	-	-	-	2	1.6 ±0.3	1.4-1.8
2	11	2.9 ±1.1	1.5-4.8	12	2.3 ±1.0	1.1-3.9
3	43	2.5 ±1.2	0.9-7.0	25	2.2 ±1.0	0.7-5.0
4	43	3.0 ±1.3	1.2-8.3	23	2.8 ±1.3	0.8-5.4
5	30	4.2 ±1.7	1.3-6.9	10	2.6 ±1.3	1.3-5.3
6	13	4.6 ±1.6	1.7-8.3	5	3.5 ±1.1	2.3-5.2
7	4	4.2 ±1.4	2.7-6.1	-	-	-
max*	44	4.6 ±1.7	1.5-8.3	25	3.5 ±1.2	1.9-5.4

* max implies the maximal stage reached by the subjects and ranges from stage 2 - 7.

Table 3: Pearson product correlations for the best predictors of the measured $\dot{V}O_2$ max from the submaximal EXPES step test.

Variable	r
Lactate	-0.33
Age	-0.26
Weight	-0.14
Stage Heart Rate	-0.02

Lactate and Stage Heart Rate values were measured after the completion of the 4th Stage of the EXPRES step test.

Table 4: Multiple correlations from stepwise regression for predicting directly measured $\dot{V}O_2$ max from EXPRES variables and lactate without the use of heart rate.

Variable(s)	Multiple R
Lactate	0.332
Lactate+Age	0.440
Lactate+Age+Fin St $\dot{V}O_2$*	0.446
Lactate+Age+Fin St $\dot{V}O_2$+Wt**	0.448

* Fin St $\dot{V}O_2$ implies $\dot{V}O_2$ for the Final Stage of the EXPRES test which was completed by the subject.

** Wt implies Weight

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